No. 160.

THE UNIVERSITY OF LEEDS
AND THE
YORKSHIRE COUNCIL FOR
AGRICULTURAL EDUCATION

SPRAIN OR INTERNAL RUST SPOT OF POTATOES

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J. Strachan, 6, Barrow Lane, Hessle, E. Yorks.
H. Thompson, Carleton, Pontefract.

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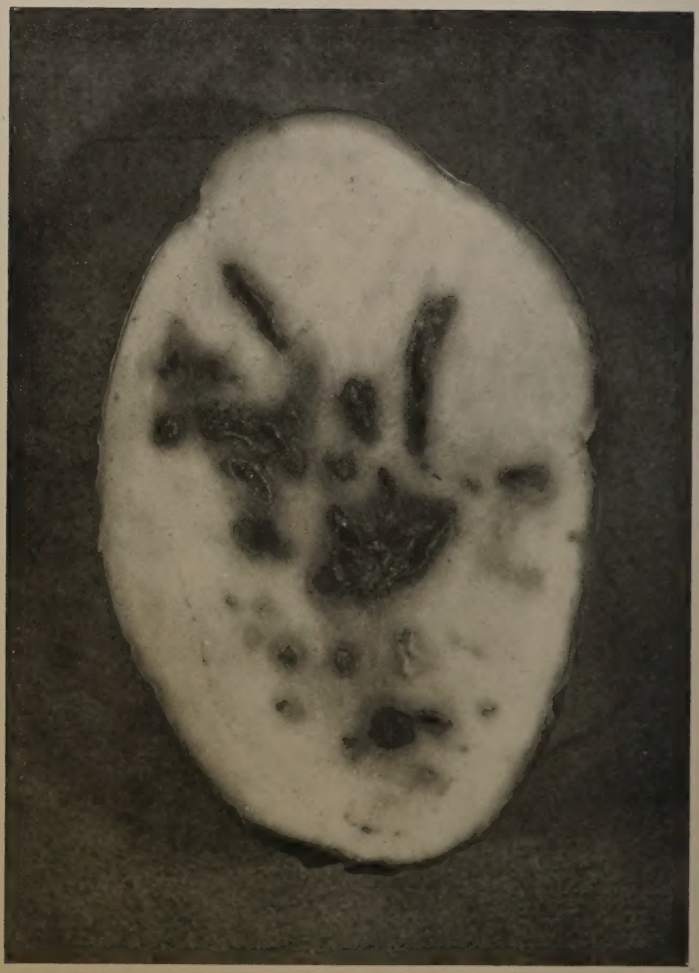

FIG. 1.

A naturally infected tuber after four months' storage showing Sprain lesions.

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The University of Leeds
AND
The Yorkshire Council for Agricultural Education.

Sprain or Internal Rust Spot of Potatoes.

Bacterium rubefaciens.

Sprain belongs to that group of potato diseases which reveal their presence only when the crop is lifted and are thereby a source not only of financial loss but of irritating disappointment. The disease is widespread and appears on nearly all soils sufficiently light to be regarded as suitable for potato culture. Thus, during the time that the writer has interested himself in the disease, he has received samples which were severely " sprained " from places as far removed as the South of England and the North of Scotland. The disease has also been reported in the official records of the Ministry of Agriculture and Fisheries from various parts of the country. In general, the attacks are slight and cause relatively little depreciation in the value of the crop, but in certain districts serious outbreaks occur which cause great damage.

During recent years the attention of the writer has been directed to an attack of this kind in a potato growing area in Yorkshire. Here, the disease known locally as Canker, seems to be of comparatively recent origin. According to the farmers in the district it appeared in its present virulent form in 1923, since when it has recurred each year with but slight variations in intensity. So destructive is it that infected crops not disposed of before Christmas are by then practically worthless.

An investigation of this disease has now been completed at this University and a full account* of the experimental work done in establishing its causative organism and the nature of its attack has recently been published in the current number of the *Annals of Applied Biology*, Vol. XV., No. 4, Nov. 1928. In that account it was not possible for lack of space to include any record of the trials of a number of varieties for resistance to the disease or of the field experiments carried out for its control. These results are therefore herewith recorded for the first time and a short summary of the more technical part of the investigation will be added in the interest of those who have not the time to read, nor the necessary training to appreciate the fuller account already mentioned.

Description of Sprain.

The disease first appears in the form of minute, rusty brown spots irregularly distributed in the flesh of the tuber. In the more susceptible varieties these spots may easily be seen by slicing the potato through at the time of lifting, but they are always small and to the uninitiated may cause little alarm. In other varieties the spots at this stage are mere pin points or their location may

*This account also includes a description of a minor disease called *Corky Bacteriosis* which may accompany Sprain, but which for the sake of clearness is omitted from the present record.

not even be apparent to the naked eye. During storage the disease develops rapidly until finally nearly the whole of the flesh of the tuber may be destroyed. The significance of the local name "Canker" is then fully appreciated. At this later stage reddish brown spots in all degrees of development may be seen. The larger spots or blotches are very irregular in shape, deep rusty brown in colour, and in each, a central cavity will have appeared (Fig. 1). Eventually, the whole potato becomes hard and corky in texture and this, combined with a shrivelling of the skin, produces an appearance which is very reminiscent of Dry Rot.

Type of Soil on which the disease appears.

Reference is made in all previous accounts of the disease to the fact that Sprain occurs most commonly on light, sandy soils and the soil of the district in which this investigation was carried out confirms this observation. Analyses of two samples A. and B. from a field in which a very badly sprained crop had been grown are given below :—

ANALYSES OF SOIL SAMPLES.*

	Sample A.	Sample B.
Lime requirement	Nil.	Nil.
pH (colorimetric method)	6.6	6.7–6.8
Mechanical Analysis.	%	%
Fine Gravel	0.60	0.56
Coarse Sand	59.18	52.25
Fine Sand	23.68	28.21
Silt	2.60	2.93
Fine Silt (*a*)	2.75	3.89
Fine Silt (*b*)	2.95	2.38
Clay	1.10	1.00
Moisture	1.58	1.75
Loss on ignition	3.58	4.41
*Loss on solution (N/5 HCl)	2.99	3.86
	101.01	101.24
Carbon dioxide	0.510	0.562
*containing Calcium carbonate	0.80	1.01
Magnesium carbonate ..	0.34	0.25

The Loss on Ignition includes the Carbon dioxide so that the organic matter in each sample is 3.07% and 3.85% respectively.

*Analyses kindly carried out by Mr. H. Trefor Jones, M.Sc., Assistant Lecturer in Agricultural Chemistry and Advisory Chemist, University of Leeds.

It is obvious from these analyses that the soil was of a very sandy nature containing over 80% of coarse and fine sand. The analyses also reveal the remarkably low organic matter content of the soil as compared with a medium loam which normally shows an organic matter content of from 7–8%. Further evidence of this shortage of organic matter is the fact that potatoes grown on this land not only suffer from Sprain but are also badly scabbed when, as in the case of the samples analysed, the lime requirement has been made good. That the shortage of organic matter, coupled with the occurrence of Scab, is a combination of cause and effect has already been demonstrated by previous investigations (1) in this department and further reference will be made to it in dealing with Control measures for Sprain.

Internal Structure of the disease spots.

In addition to Sprain, there are a number of other diseases which produce a browning of the potato flesh, and in order to avoid any possible confusion with these, a careful study was made of the microscopic structure of Sprain lesions in all stages of development. Fig. 2 illustrates an early stage of the disease by a section through a spot from 2-3 mm. in diameter occurring in the cortex of the tuber, *i.e.* the band of tissue between the vascular ring and the skin. The spot consists of a group of parenchymatous (or ground tissue) cells the walls of which have become brown, thickened and lignified. In healthy tissues all such cells are packed with starch grains and it will be seen that within the diseased spot some of the affected cells still retain their starch. The spaces between the grains are densely packed with minute, granular bodies apparently of a proteid nature. A zone of brick-shaped cork cells from 4 to 10 cells thick has formed around the diseased group of cells and may be regarded as the effort of the tuber to protect the still healthy tissues from further invasion. This attempt is sometimes successful, and when so, the spot ceases to enlarge ; more often, the corky zone does not complete its ring of defence in time to prevent the disease from spreading outwards through gaps as shown at " d " in the figure. The spot thus becomes irregular in shape and often turns into a streak. A remarkable feature of the disease is the consistency with which the structure described repeats itself in all young Sprain spots and thus constitutes a definite means for its identification.

(1) Report 118. Common Scab of Potatoes. Univ. of Leeds and Yorks. Council for Agric. Educ.

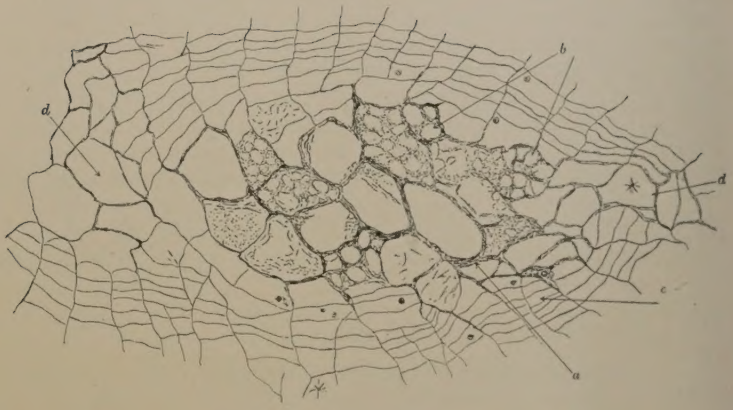

FIG. 2.

Section through a small spot of Sprain in the cortex of a naturally infected tuber showing some empty cells and other cells filled with starch grains: (*a*) thickened, suberized and lignified cell walls; (*b*) starch grains in cells; (*c*) cork; (*d*) points at which the disease has spread outwards before the cork layer was complete.

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In older spots, the central core of cells has invariably collapsed forming a cavity lined with their debris.

Some modification of these structural characters occurs when the spots are produced in the relatively moister pith of the tuber, where the cells are often less densely packed with starch. Here, the corky layer arises at a somewhat further distance from the seat of infection and its development is slower and weaker. For this reason perhaps the larger diseased areas are usually found in the pith or central portion of the tuber. In spite of these modifications the essential features of the spots, whether they arise in the cortex or in the pith are the same and serve to differentiate the disease from all others.

Origin and Transmission of the disease.

The statement has been made by previous investigators that Sprain is not transmitted by diseased seed when the latter is grown on clean soil, *i.e.* soil on which clean crops are ordinarily raised. The idea is also prevalent among farmers that clean crops may be raised from infected seed provided this is grown on heavy land.

In order to test the truth of these statements 50 tubers of "Golden Wonder" from a badly diseased crop were grown in a plot at the University Farm, Garforth, where the soil is a medium loam. The crop was stored for four months after lifting and at the end of this time 100 tubers were carefully sliced and examined. In 58 of these tubers one or two minute specks of sprain were found. These spots were too small to be noticed unless they were especially sought and for all practical purposes the crop was a clean one. Again, when some diseased potatoes from the same source were allowed to tuberize in the laboratory, one of the young tubers was found to show two distinct Sprain spots, whilst, the remainder were quite clean. It would seem then that, whilst Sprain is certainly transmissible from the mother tuber to its progency, the degree of disease so produced is very slight.

The evidence of practical experience points to the soil as the main source of infection. On the farms where it is so prevalent it has long been the custom to use new Scotch seed every year or every second year and the crop from this has been equally infected with that raised from once-grown seed. On the other hand, the writer once had the experience of purchasing a quantity of Scotch seed which whilst otherwise extremely good, was badly infected with Sprain. It was thought desirable, therefore, to grow some tubers free from any suspicion of Sprain in soil taken from a field where the disease appears. For this purpose tubers were taken from a consignment of seed of which for another purpose a large quantity had been cut and found to be absolutely free from spots or blemishes of any kind. Two tubers from this sample were cut and found to be clean and after the cut surfaces had healed, two of the half tubers were planted in pots of soil brought from the infected field and the other two in pots of the same soil which had been sterilised by heat. The progeny of the first two pots was very badly sprained, whilst that from the last two was quite free from the disease. The experiment thus affords unassailable evidence that the disease originates from the soil and in addition, it offers presumptive evidence that infection occurs through some organism in the soil which is killed by heat.

The Organism of Sprain.

The search for the organism causing Sprain has not been confined to workers in this country for the disease is also common in Holland and Germany and mycologists in both these countries have also made serious, though abortive efforts to ascertain its cause. In face of these failures we feel that we owe our success mainly to the fact that we had at our command an unlimited quantity of material from which to obtain specimens of the disease in all stages of development.

Examinations of the larger cavitied lesions showed that they were often inhabited by fungi and bacteria in large numbers. Cultures of these were made and among the fungi, two known as *Rhizoctonia solani* (Kühn) and *Nectria inventa* (Pethybridge) were found to be dominant, whilst the bacteria were of varied types. It became obvious that this mixed flora, whilst doubtless aiding tissue destruction after the initial attack, were probably camp followers of the primary parasite, if such existed.

Attention was therefore focussed on the smaller spots in which no cavities had as yet appeared. Here, after microscopic examination, no threads could be found and no bacteria were demonstrated with certainty. All attempts to grow any organisms present in the spots on the artificial media commonly used for this purpose in the laboratory met with failure. Finally, however, a decoction of the soil on which the disease occurred was made and sterilized giving a light brown opalescent liquid. Into each of twelve tubes of this media the whole of a small spot of the disease, removed from the tuber under aseptic conditions, was dropped. The tubes were then placed in an incubator at a temperature of 25°C. After 4 days it was seen that the liquid in three of the tubes showed a faint opacity and when a drop from each was removed, it was possible to demonstrate the presence therein of rodlike organisms or bacteria. These were extremely minute, measuring 0.0016 mm. or 1 16,000 inch in length and 0.0005 mm. or 1 50,000 inch in breadth. Later, growth was obtained on soil extract made into a jelly with Agar-agar, but here, the growth was remarkably slow and colonies only became visible to the naked eye after 10 days. For details of the subsequent cultural work the reader must be referred to the scientific paper already mentioned. Suffice it to say that the minute dimensions of the organisms combined with their intolerance of growth in artificial media made their study an extremely difficult one.

In 1926, pots of sterilised soil were inoculated with cultures of this organism and in these, potato crops were raised. In a considerable number of the tubers thus obtained typical Sprain spots were reproduced which, on sectioning, showed all the morphological characters of the disease. These infection experiments were repeated on a larger scale in 1927 with similar positive results. The organism isolated must therefore be considered as the causative agent of the disease, and since it is new to the literature it has been named *Bacterium rubefaciens*. n.sp.

Variety Trials for Resistance to Sprain.

Eighteen well known varieties of potatoes were grown in 1926 on badly infected soil in order to ascertain whether they showed any differences in susceptibility to the disease. Each variety plot consisted of two rows 116 ft. long on a part of the field where, in previous crops, the disease had been uniformly bad. With the exception of Kerr's Pink where the seed used was once-grown, the seed of all varieties was new from Scotland.

Each of the early varieties was lifted soon after it had died down and the second early and late varieties on October 20th, 1926. A preliminary examination of each crop was made at the time of lifting with the results shown in Table I. Each variety was then separately pied and a further and more detailed examination made on February 20th, 1927. These results are given in Table 2.

In each examination fifty tubers of each variety were cut into thin slices about 3 mm. thick, so that even small spots of disease might be detected. It became quickly apparent that the size and number of spots or streaks in the infected tubers from different varieties varied considerably. For this reason, in addition to counting the number of infected tubers, an estimate was also made by eye of the severity of attack in each variety. It is this severity of infection which, from the practical standpoint, is the crucial test since, for purposes of sale, minute specks of disease may be disregarded. This being so, the figures given in the column headed "Degree of Disease" are to be regarded as of the greater consequence. The maximum degree of disease is represented by the number 12, and the degrees are so estimated that those varieties having a figure greater than 7 would be quite unsaleable, whilst those with a figure of 2 or less would be only slightly reduced in value, provided they were sold for immediate consumption.

Table 1.

Date of Examination—26th October, 1926.

Variety.	% Number Infected Tubers	Degree of Disease. Max = 12
EARLY VARIETIES—		
Sharpe's Express	20	1.0
Resistant Snowdrop	28	1.0
Arran Rose	24	1.0
SECOND EARLY VARIETIES.—		
Arran Comrade	52	1.0
Arran Chief	40	0.5
Ally	48	1.0
Great Scot	48	1.0
British Queen	40	2.0
LATE VARIETIES—		
Golden Wonder	88	5.0
Majestic	40	0.5
Tinwald's Perfection	24	0.5
Field Marshal	72	3.0
Catriona	12	0.1
King Edward	36	1.0
Rhoderick Dhu	52	1.0
Bishop..	48	2.0
Crusader	32	0.2
Kerr's Pink	50	1.0

It will be seen that although in nearly all varieties the percentage of infected tubers was high, yet the degree of disease was generally very low indeed. With the exception of Golden Wonder, Field Marshal and Bishop any of the varieties at this time might easily have been sold as clean crops.

Table 2.

Date of Examination, February 20th, 1927.

Variety.	% Number Infected Tubers.	Degree of Disease. Max.=12.
EARLIES—		
Sharpe's Express	40	5.0
Resistant Snowdrop	10	0.2
SECOND EARLIES—		
British Queen	58	7.0
Arran Comrade	50	0.5
Great Scot	32	4.0
Ally	48	4.0
Arran Chief	52	0.5
LATES—		
Majestic	36	2.0
Kerr's Pink	50	5.0
Tinwald's Perfection	44	2.0
Field Marshal	64	10.0
King Edward	36	3.0
Golden Wonder	68	10.0
Bishop..	68	12.0
Crusader	60	10.0
Rhoderick Dhu	42	3.0
Catriona	12	0.5

The degree of disease shown in this examination is much greater than that of the first and fully confirms the statement that the disease is mainly one of storage. A comparison of the two tables shows that the percentage of infected tubers found in the two examinations differs very considerably for certain varieties, and demonstrates the unreliability of this count as a comparative test. Conclusions in regard to varietal susceptibility are therefore drawn from the degree of disease given in column 3. From this, it is seen that a very great difference in susceptibility to Sprain is to be found among the different varieties and in Table 3 these have been tabulated in order of their resistance to the disease.

Table 3.

Varieties of Potatoes in order of resistance shown to Sprain in trials carried out in 1926.

(1) Crop very slightly damaged and little reduced in value : —

Resistant Snowdrop.	Catriona.
Arran Chief.	Majestic.
Arran Comrade.	Tinwald Perfection.

(2) Crop considerably damaged but saleable :—

Rhoderick Dhu.	Ally.
King Edward.	Great Scot.

(3) Crop badly damaged and scarcely saleable :—

Sharpe's Express.	Kerr's Pink.
British Queen.	

(4) Crop ruined and unsaleable :—

Crusader.	Golden Wonder.
Field Marshal.	Bishop.

Measures of Control.

A first series of experiments was carried out in 1926 with the object of ascertaining whether there was any means of checking or eradicating the disease. Plots one fiftieth of an acre in area, consisting of three rows of potatoes, each 116 ft. long, were laid down on infected soil and treated as shown in the following table : —

No. of Plot.	Treatment.
1 ..	Green manured.
2 ..	Ground lime at the rate of 3 tons per acre.
3 ..	Ground lime ,, ,, 10 ,, ,,
4 ..	Control (1).
5 ..	Flowers of Sulphur at the rate of 5 cwts. per acre.
6 ..	Flowers of Sulphur ,, ,, 10 ,, ,,
7 ..	Sulphate of Ammonia ,, ,, 5 ,, ,,
8 ..	Control (2).
9 ..	Flowers of Sulphur ,, ,, 10 ,, ,,
10 ..	Superphosphate of Lime, ,, ,, 10 ,, ,,
11 ..	Sulphate of Potash ,, ,, 5 ,, ,,
12 ..	Sulphate of Potash ,, ,, 10 ,, ,,
13 ..	Control (3).

All the plots were given farmyard manure at the rate of 20 tons per acre, but no artificials other than those in the treatment were used. The seed was Kerr's Pink. The green manured plot was prepared by sowing it thickly with rye, on 13th October, 1925, and in order to increase the bulk of the green top, a dressing of Nitrate of Soda was applied early in March, 1926. Unfortunately, sheep broke into the field on two occasions and ate down the rye,

so that when this crop was ploughed in, its bulk was very much less than had been intended. Both the Ground Lime and Sulphur were applied and harrowed in in October, and the remaining treatments were given immediately before planting on April 15th, 1926. Reasonably good crops were obtained on all plots, and these were lifted on October 20th. The crop from each plot was separately pied and was examined at intervals during the winter. The three control plots had been purposely placed between the treated plots in such a way that one lay in the centre and the other two at either end of the experimental area. In this way any difference in degree of soil infection which might possibly occur across the plots would be indicated. In the results, it was found that the infection in Control plot (1) was slightly less than in Control plot (2) and that, again, Control plot (2) was slightly less infected than Control plot (3). It may be taken then that, in passing from Plot 1 to Plot 13, soil infection slightly increased. Too much stress need not be laid on this slight lack of uniformity, since the crop from each of the Control plots was so badly diseased that by January, 1927, it was unsaleable. On no plot were the potatoes free from disease but certain differences in the degree of disease were plainly shown. An examination of the crops was made on the 26th October, 1926, and again on the 26th February, 1927. In each case, one hundred tubers from the separate pies were cut and the percentage of diseased tubers estimated. An estimate of the degree of disease in each crop was also made as in the variety trials, taking 100 as the figure for maximum tissue damage.

The results of the final examination are given in Table 4.

Table 4.

Final Examination of Crops. 26th February, 1927.

No. of Plot.	Treatment.	% Diseased Tubers in Crop.	Degree of Disease in Crop.	Value of Crop.
1	Green Manure	28	10	Saleable.
2	Ground Lime 3 tons ..	36	20	,,
3	,, ,, 10 ,, ..	44	10	,,
4	Control (1)	56	90	Unsaleable.
5	Sulphur 5 cwt.	68	90	,,
6	,, 10 ,, (1) ..	68	80	,,
7	Sulphate of Ammonia 5 cwt.	72	50	,,
8	Control (2)	68	95	,,
9	Sulphur 10 cwt. (2) ..	56	80	,,
10	Superphosphate 10 cwt. ..	64	90	,,
11	Potash, 5 cwt.	64	50	,,
12	,, 10 cwt.	64	50	,,
13	Control (3)	76	100	,,

It will be seen that a slight reduction in the degree of the disease was produced by the treatment with Sulphate of Ammonia and with Potash. A much greater reduction was given by lime and by green manuring, and in the plots so treated the amount of disease, although appreciable, would not have reduced the value of the crop very seriously. It was very difficult to understand why two treatments, so obviously different, should have produced effects equally beneficial and since the three plots concerned, Nos. 1, 2 and 3 happened to be adjacent to each other and to lie at one end of the experimental area, the results were regarded with some suspicion. At the same time, the disease on Plot 4 was very abundant and it was impossible to think that there could be a sharp division in soil infection between this plot and Plot 3. The results were sufficiently interesting to lead us to repeat the treatments in the following year.

In 1927 the experiment was carried out on another field where the soil was of the same nature and the potato crops equally attacked by the disease. Seven plots, each consisting of 4 rows of potatoes, 52 ft. long were laid down and each plot was separated from the next by two untreated rows. The plots were as follows :-

No. of Plot.	Treatment.
1 ..	Green Manure.
2 ..	Control.
3 ..	Cresylic Acid.
4 ..	Ground Lime 5 tons per acre.
5 ..	„ „ 10 „ „
6 ..	Sulphate of Potash 10 cwt. per acre.
7 ..	Sulphate of Ammonia 5 cwt. per acre.

In this case a very heavy green crop was obtained and ploughed in for Plot 1. The cresylic acid used consisted of a mixture of lime and cresylic acid containing 15% of the latter and was applied at the rate of 10 cwt. per acre. In this experiment the dressings (including that of the lime) were applied in the spring about one month before planting. The seed potatoes used were Field Marshal, once grown at Garforth and tree from Sprain. No Farmyard manure was applied to the plots, but all were given complete dressings of artificials. The crops were separately pied and were examined on the 2nd December, 1927, and again on the 26th March, 1928. The final results are shown in Table 5.

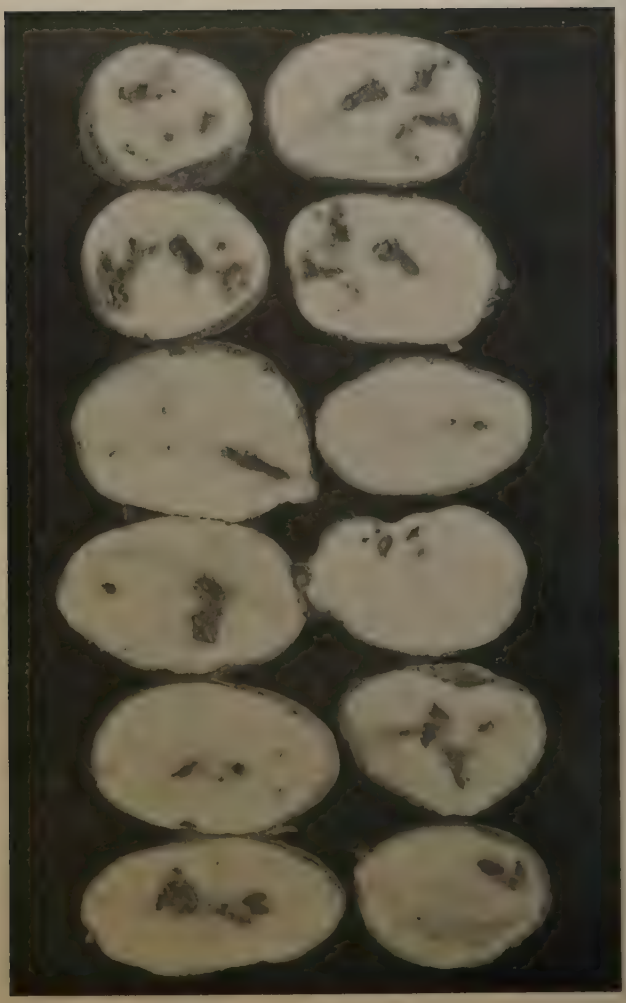

FIG. 3.

The halves of 12 tubers taken at random from the untreated plot in the field experiments 1926—showing typical Sprain.

FIG. 4.

The effect of green manuring. The halves of 12 tubers taken at random from the green-manured plot in the field experiments 1926 one tuber only showing Sprain.

Table 5.

Final Examination of Crops, 26th March, 1928.

No. of Plot.	Treatment.	% Diseased Tubers in Crop.	Degree of Disease in Crop. Max. = 100.	Value of Crop.
1	Green manured	22	2	Slightly reduced in value but saleable.
2	Control	97	100	Unsaleable.
3	Cresylic Acid	80	50	Unsaleable.
4	Ground Lime (5 tons) ..	74	36	Unsaleable.
5	Ground Lime (10 tons) ..	40	7	Reduced in value but saleable.
6	Sulph. of Potash (10 cwt.)	82	35	Unsaleable.
7	Sulph. of Ammonia ..	70	30	Greatly reduced in value but, perhaps saleable.

The results were generally confirmatory of the previous year's experiment. Both sulphate of ammonia and potash had exerted some inhibitory effect on the disease, but not to an extent worth considering. The action of lime was extremely interesting. On Plot 5, the larger dressing yielded a crop which was remarkably clean ; not only was the infection of Sprain reduced to comparatively slight proportions, but the tubers were absolutely free from Scab and in this respect, made a striking contrast with the crops on the plots adjacent to it. The inference might easily have been drawn that a heavy dressing of lime was a cure for scab. Obviously, the true explanation of the result was that the heavy dressing of quicklime had brought about an almost complete sterilisation effect as far as Actinomyces—the scab organism and the Sprain bacteria were concerned. Concurrently with this effect it should be noted that the bulk of crop from this plot was reduced to less than half that of the other plots. No effects of this kind were found on Plot 4 where the smaller dressing of lime was used. We must conclude therefore, that from a practical standpoint, liming is not likely to be of service as a preventive measure for Sprain.

The outstanding result of the experiment is that provided by the green-manured plot. Here, the percentage of tubers in which infection was found after careful slicing was 22, but, on most of the tubers

the spots would have escaped the attention of a casual observer. In order to make a further comparison between this crop and that of the control, twelve tubers were taken at random from each and cut in halves. A photograph of the half tubers from the control plot is shown in Fig. 3 and that of the half tubers from the green manured plot in Fig. 4. This result abundantly confirms that of the 1926 experiments and in our opinion establishes green-manuring as a treatment which can be thoroughly recommended for Sprain. It is particularly interesting in view of the fact that the soil on which the disease was so virulent is one which is naturally very deficient in organic matter. It has already been stated that the potato crops on this land scabbed badly and this association of Scab and Sprain on the same soil led us to surmise a common causal factor for their appearance—namely the lack of a sufficient supply of organic matter. If this were so, then it was natural to assume that green manuring, which is so effective in the control of Scab, might also be the antidote for Sprain. The results appear to justify the assumption in the most happy way.

To those farmers who are troubled with this disease and who, after reading this article, are desirous of carrying out the green manuring treatment recommended, we would make the following suggestions. In the first place, the green crop must be one which will stand the winter and which will give a bulk of leafy foliage in the early spring. Mustard may answer the purpose in the South of England but, in the North, a cereal crop is best and Rye is strongly recommended. The best effect on the Potato crop will probably be obtained as in the case of Common Scab—by ploughing in the crop at as late a date in spring as is compatible with the planting of the potatoes. Here, however, a difficulty arises in that the vegetable matter does not decay quickly enough to allow of the furrows for the potatoes being made without bringing a good deal of the green manure to the surface. On land which is not too light this obstacle may be overcome by ridging up the land in the autumn previous to sowing the green crop. The latter is then allowed to remain until the time for potato planting, when the manure should be spread in the furrows. The green-crop is thereby considerably trampled down and the potatoes can be planted. The rows are then split. By this means the green crop will fall into the furrows and be sufficiently covered by the soil. It will moreover become incorporated with the upper spit of soil in which the new tubers are eventually formed and thus exert its fullest effect in warding off the attack of the Sprain organisms. A word of warning should perhaps be added to the effect that where the method suggested is followed, the green crop should not be so heavy as to produce overheating or to smother the potatoes. Under ordinary farming conditions this would be very unlikely to occur except where an excess of zeal in raising the green crop got the better of discretion.

SUMMARY.

Sprain, or Internal Rust Spot, is a potato disease which has long been known and is widely distributed both in this country and on the Continent.

In Yorkshire it is known as " Canker " and occurs in a virulent form in certain areas where the soil is a light sand very deficient in organic matter. The same soil yields badly scabbed crops in cases where lime has been freely applied.

The first symptoms of Sprain are small rusty brown spots in the flesh of the tubers which may be no larger than a pin's head; these are distributed indiscriminately in the tuber flesh and are of a hard corky nature.

In some varieties of potatoes these spots are to be found when the crop is lifted, but in many varieties, affected tubers show practically no visible signs of the disease until some time after having been stored.

The disease develops rapidly in storage. Spots present when the tubers are lifted increase in size producing irregular blotches or streaks within which cavities are often formed. Meanwhile, new spots arise and follow the same course. In badly affected tubers groups of spots may coalesce to form large, rusty brown areas an inch or more in diameter and in this way, practically the whole of the tuber flesh may be destroyed. Eventually, the interior of the potato becomes hard and corky in texture and the skin shrivels. Up to this time the external appearance of the tuber gives no indication of the disease within, unless, as sometimes happens, disease spots abut on the rind—a slight shrivelling of the latter may then be found immediately above the diseased area.

Crops which are severely attacked by Sprain become greatly depreciated in value when stored until the end of the year and a month or two later than this they may be unsaleable.

In a series of variety trials carried out in 1925 some varieties (*e.g.* Golden Wonder, Bishop and Field Marshal) proved very susceptible to the disease; others (*e.g.* King Edward, Great Scot) were less susceptible and some (*e.g.* Resistant Snowdrop, Catriona, Majestic) were highly resistant.

Experiments carried out in 1926 and repeated in 1927 indicated that some reduction of the disease was brought about by heavy dressings both of Sulphate of Potash and Sulphate of Ammonia, but, on the heavily infected land in question, this reduction was not sufficient to be worth considering. A similar inhibitory effect was

produced by Ground Lime when applied in very heavy dressings and to a still lesser extent by a Cresylic acid mixture. Flowers of Sulphur and Superphosphate of Lime exerted practically no control of the disease. On the other hand green-manuring, that is the ploughing in of a green crop before planting the potatoes proved highly successful in warding off the disease. In the 1927 crop grown under this treatment only the slightest infection appeared even when the potatoes had been stored till the end of March. Green manuring as described in this paper may therefore be strongly recommended as a preventive measure against Sprain or "Canker."

The writer wishes to express his great indebtedness to his colleague, Mr. W. A. Millard, D.Sc., for the invaluable help and guidance which he has so generously given him during the course of this investigation. His best thanks are also due to Mr. J. Manby for the photographs.

SYDNEY BURR.

THE UNIVERSITY,
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